TOPIC 08 – ACIDS/BASES
8.1 – THEORIES OF ACIDS AND BASES

IB Chemistry

T08D01

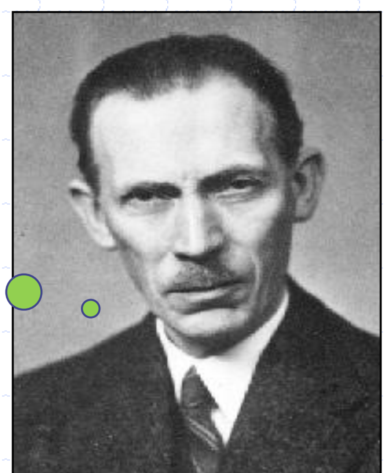
8.1 Theories of acids and bases - 2 hours

- 8.1.1 Define acids and bases according to the Brønsted–Lowry and Lewis theories.(1)
- 8.1.2 Deduce whether or not a species could act as a Brønsted–Lowry and/or a Lewis acid or base. (3)
- 8.1.3 Deduce the formula of the conjugate acid (or base) of any Brønsted–Lowry base (or acid). (3)

8.1 - Brønsted–Lowry Definition

- **Brønsted–Lowry Definition:**
- Focus is on the transfer of protons (a positively charge hydrogen atom – H^+)
  - **B/L Acid** is defined as a molecule (or ion) that acts as a proton donor
  - **B/L Base** is defined as a molecule (or ion) that acts as a proton acceptor

He looks
like someone
Familiar…….



8.1 – What is the Acid, Base?

- $HCl\ (g) + H_2O\ (l) \rightleftharpoons H_3O^+(aq) + Cl^-(aq)$
  - In the forward reaction,
    - HCl is the acid (donates H^+)
    - H_2O is the base (accepts H^+)
  - In the reverse reaction,
    - H_3O^+ is the acid (donates H^+)
    - Cl^- is the base (accepts H^+)

8.1 – Conjugate Pairs

- An acid-base reaction always involves (at least) two conjugate pairs that differ by an H^+
- A conjugate pair is:
  - An acid and it’s conjugate base
  - A base an it’s conjugate acid

8.1 – Water and Half Equations

- $HCl\ (g) + H_2O\ (l) \rightleftharpoons H_3O^+(aq) + Cl^-(aq)$

  Acid **Base** **conj acid** **conj base**

- We can split into two half-equations if we want:
  - $H^+(aq) + H_2O\ (l) \rightleftharpoons H_3O^+(aq)$
    - H_3O^+ is a conjugate acid of H_2O
  - $HCl\ (g) \rightleftharpoons H^+(aq) + Cl^-(aq)$
    - Cl^- is a conjugate base of HCl
- Water can act as an acid as well = **Amphiprotic**
- $NH_3\ (g) + H_2O\ (l) \rightleftharpoons NH_4^{\ +}(aq) + OH^-(aq)$
- **Base** **Acid** **conj acid** **conj base**

8.1 – Strength of Conjugates

- Consider the equations for hydrochloric and ethanoic acid:
- $HCl\,(g) + H_2O\,(l) \rightleftharpoons H_3O^+(aq) + Cl^-(aq)$

S.Acid **Base** **conj acid** **W.conj base**

  - In the equation with HCl, the water molecule is a much stronger base than the chloride ion and has a greater tendency to accept a proton (H^+), and the position of equilibrium will lie to the right. The strong acid (HCl) produces a relatively weak conjugate base.
- $CH_3COOH(l) + H_2O \rightleftharpoons H_3O^+(aq) + CH_3COO^-\,(aq)$

W.Acid **Base** **conj acid** **S.conj base**

  - In the equation with ethanoic acid, the ethanoate ion is a much stronger base than the water molecule and has a greater tendency to accept a proton (H^+). The weak acid produces a relatively strong conjugate base in aqueous solutions.

8.1 - Transformations

- Strong acid → Weak conjugate base
- Weak acid → Strong conjugate base
- Strong base → Weak conjugate acid
- Weak base → Strong conjugate acid

Acid	Strength	Base	Strength
H_2SO_4	Very Strong	HSO_4^-	Very Weak
HCl		Cl^-	
HNO_3		NO_3^-	
H_3O^+	Fairly Strong	H_2O	Weak
HSO_4^-		SO_4^{2-}	
CH_3COOH		CH_3COO^-	
H_2CO_3	Weak	HCO_3^-	Less Weak
NH_4^+		NH_3	
HCO_3^-		CO_3^{2-}	
H_2O	Very Weak	OH^-	Fairly Strong

8.1 – Proticity of Acids

- Monoprotic Acids contain a single proton that can be donated (**H**Cl, **H**NO_3, **H**NO_2, CH_3COO**H**)
- Diprotic Acids contain two protons that can be donated (**H_2**CO_3, **H_2**SO_4, **H_2**SO_3)
- Triprotic Acids contain three protons that can be donated (**H_3**PO_4)
- For a substance to be an acid, the Hydrogen usually has to be attached to oxygen or a halogen
  - For example, in CH_3COOH, only the **H** on "OH" is able to be donated, the three hydrogen's on carbon are non-acidic

8.1 – Nature of chemicals

- Di and tri-protic acids make things slightly tricky as they can act as acids or bases in various states.
  - $H_2SO_4 + H_2O \rightleftharpoons H_3O^+ + HSO_3^-$

    Acid **Base** **conj acid** **conj base**
  - $HSO_3^- + H_2O \rightleftharpoons H_3O^+ + SO_3^{2-}$

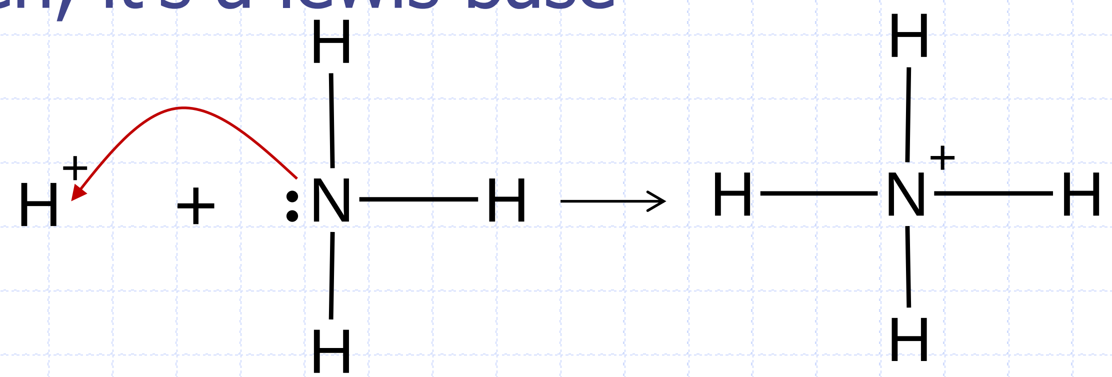
    Acid **Base** **conj acid** **conj base**
  - The term "conjugate" is a relative term
  - The term "acid" and "base" is also relative
  - You must look at what the chemical is doing in the reaction

8.1 – Lewis Definition

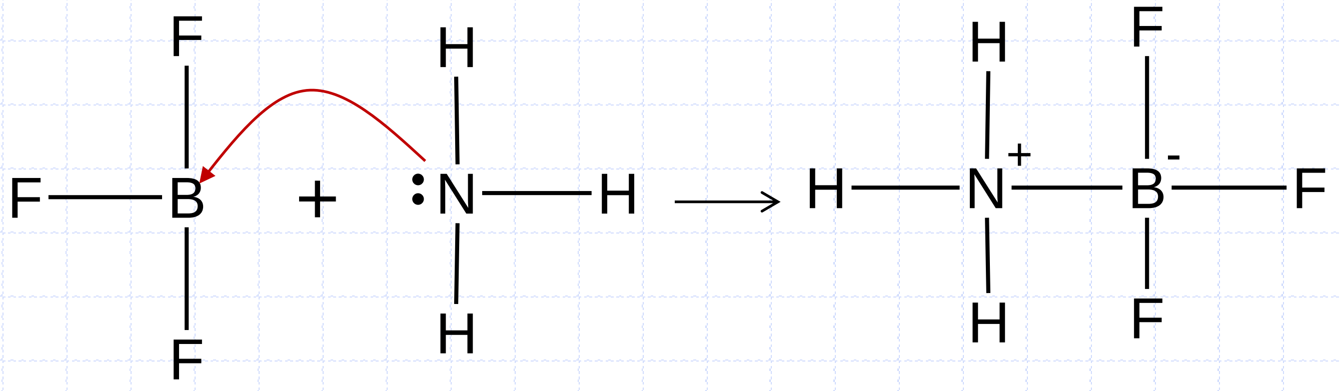
- Lewis Acid/Base Definition:
- Focuses on the transfer of electrons
  - A **Lewis acid** is an electron pair acceptor
    - In doing so a coordinate or dative covalent bond is formed
  - A **Lewis base** is an electron pair donor
    - In doing so coordinate or dative covalent bond is formed
  - A **dative** bond is one in which an uneven amount of the electrons supplied to the bond come from only one of the atoms (CN, NH_4^+, etc)

8.1 – Dative Bonds by Lewis

- When ammonia donates a pair of electrons to hydrogen, it's a lewis base



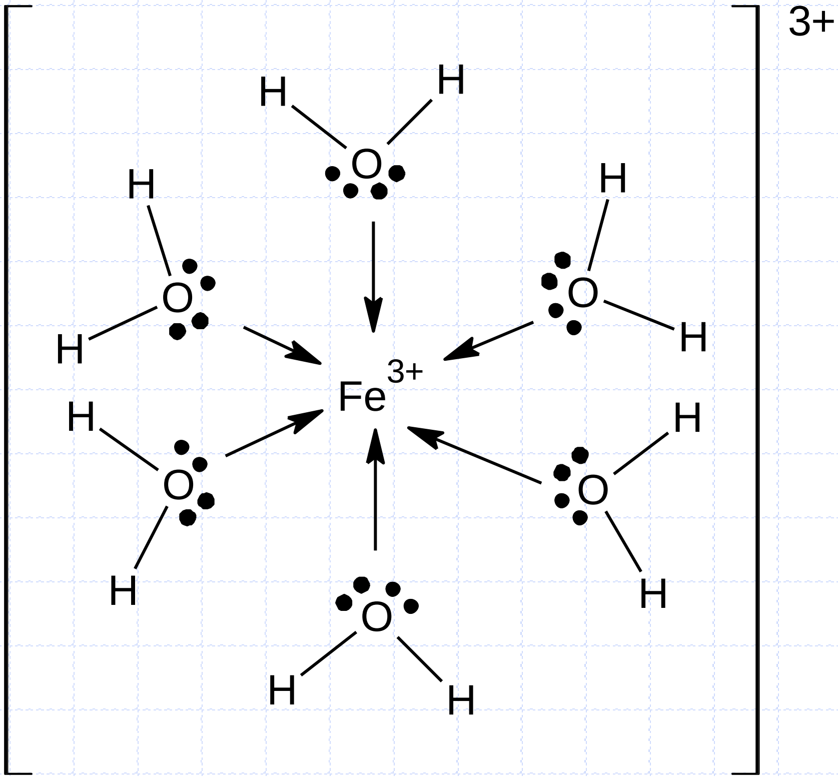
- When boron trifluoride accepts a pair of electrons from nitrogen (in NH_3) it's a lewis acid



8.1 – Transition Metals as Lewis acids

- Common examples of Lewis bonding are found in the complex ions of transition metals
- The six water molecules in $[Fe(H_2O)_6]^{3+}$ are the ligands and act as Lewis bases as they donate electrons

The electrons are donated to the empty 3d orbitals of the central transition metal

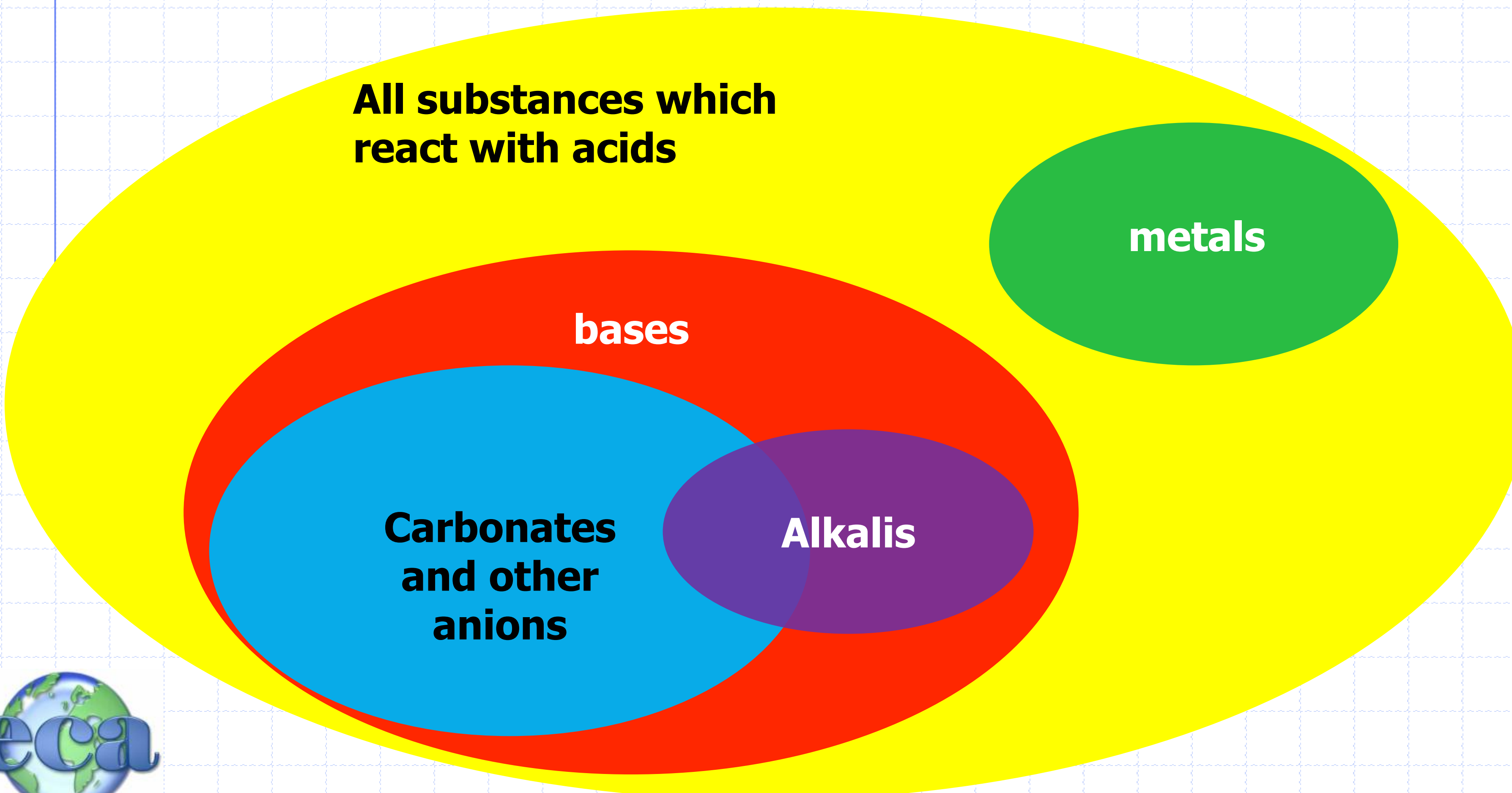


Dative bonds are often shown as arrows originating from the source of electrons in the bond

8.1 – Arrhenius Definition

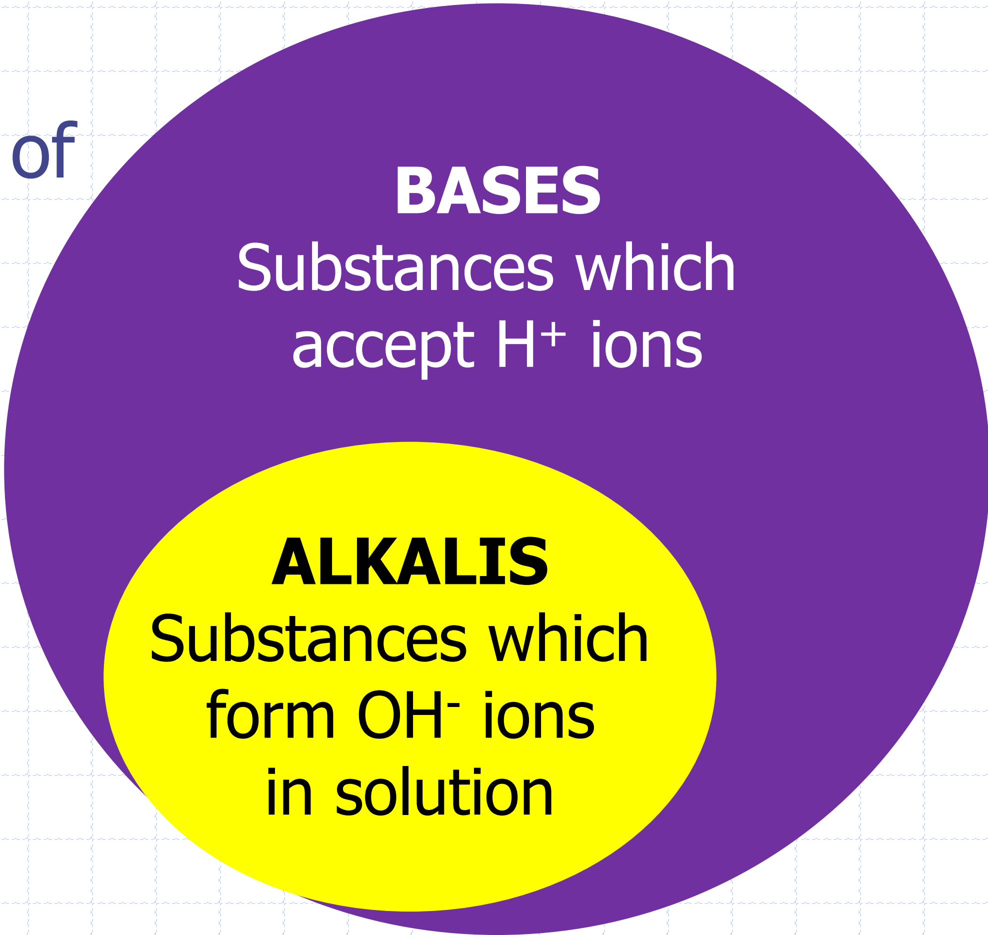
- There is one more acid base definition what is not covered in the IB but should be known.
  - Arrhenius acids donate an H^+
  - Arrhenius bases donate an OH^-
- This definition does not always work since bases such as NH_3 which do not directly contain an OH^- to be donated (although they still result in an increase in OH^- in the system
  - $NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$
  - If you ever see the formula **NH_4OH**, in solution it's simply ammonia ($NH_3(aq)$)

8.1 – Classification of chemicals which react with acids



8.1 - Clarification

- You often hear the word base used interchangeably with alkali.
- A base is defined by any of the definitions discussed
- An alkali is a base that is soluble in water



8.1 – Lewis vs Bronsted-Lowry

- All B-L acids are Lewis acids
- Not all Lewis acids are B-L acids
- The term Lewis acid is reserved for species which can only be described by the Lewis theory (those that do NOT release H^+)